Individual Cooling Element for Portable Beverage Cooling

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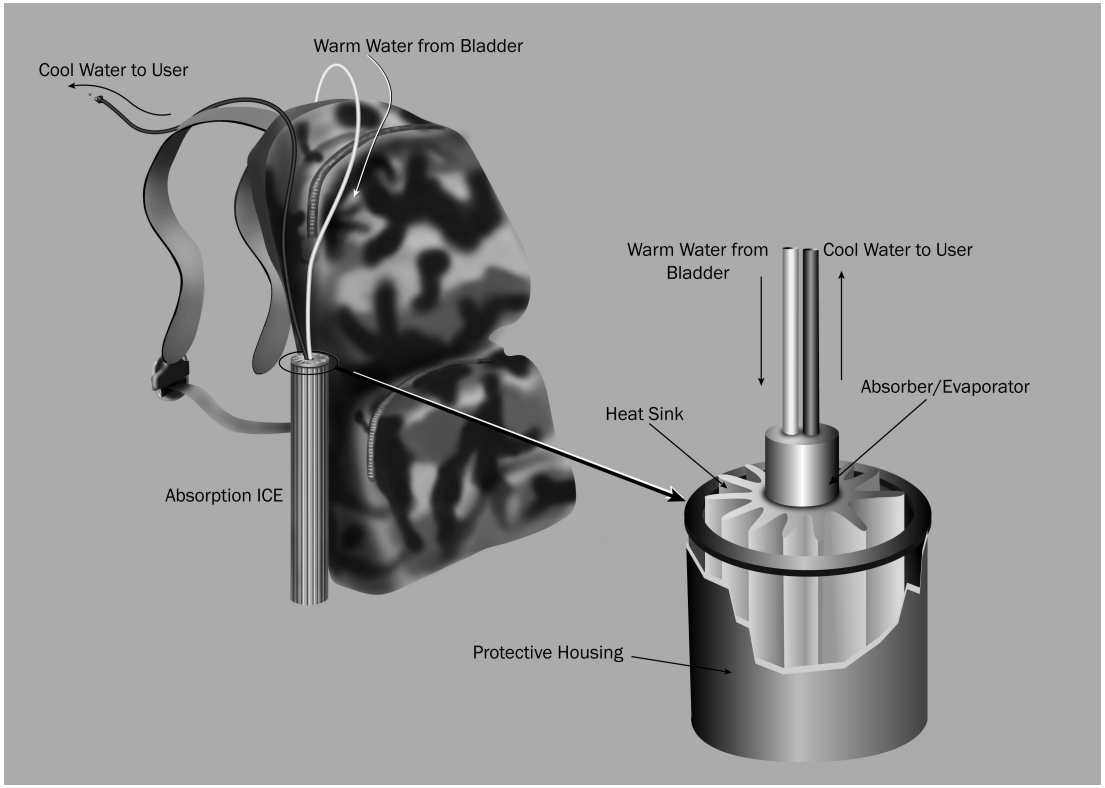
Summary

- Encourage adequate hydration
- Technical specifications for beverage cooling
- Regenerable absorption refrigeration approach
- Technology demonstrations
- Work under way

Focus on Equipment for Individual Soldiers
(Photo from CBS News)

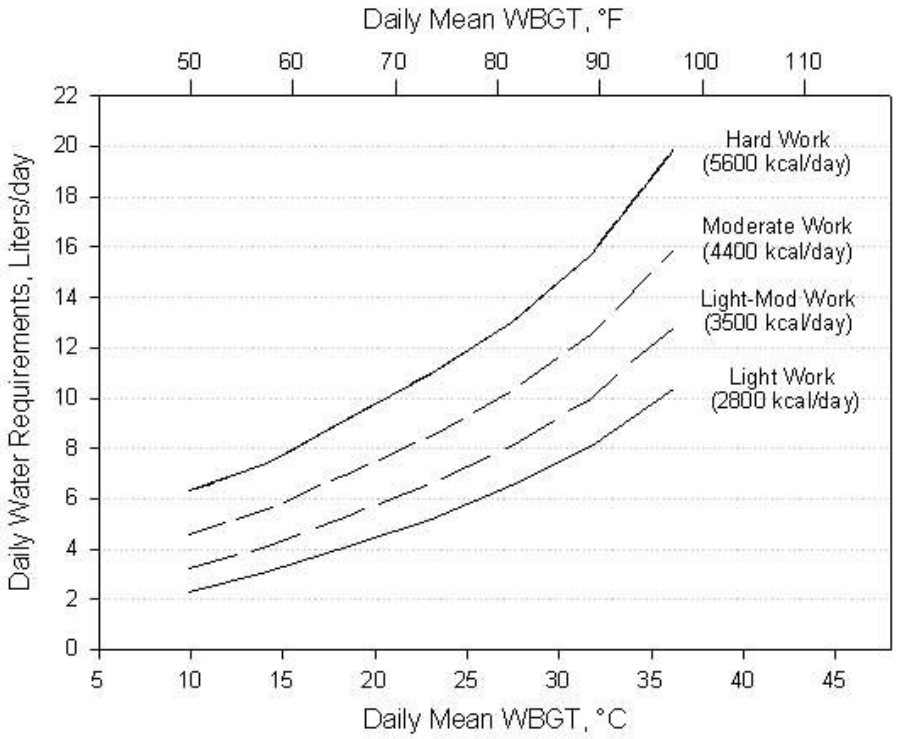
Phase I Technical Objectives

- **Goal: Safe and effective operation in hot environments**
- **Approach: Promote adequate hydration using ICEs to cool drinking water**
- **Technique: Cooling by LiCl/water absorption**



Requirements

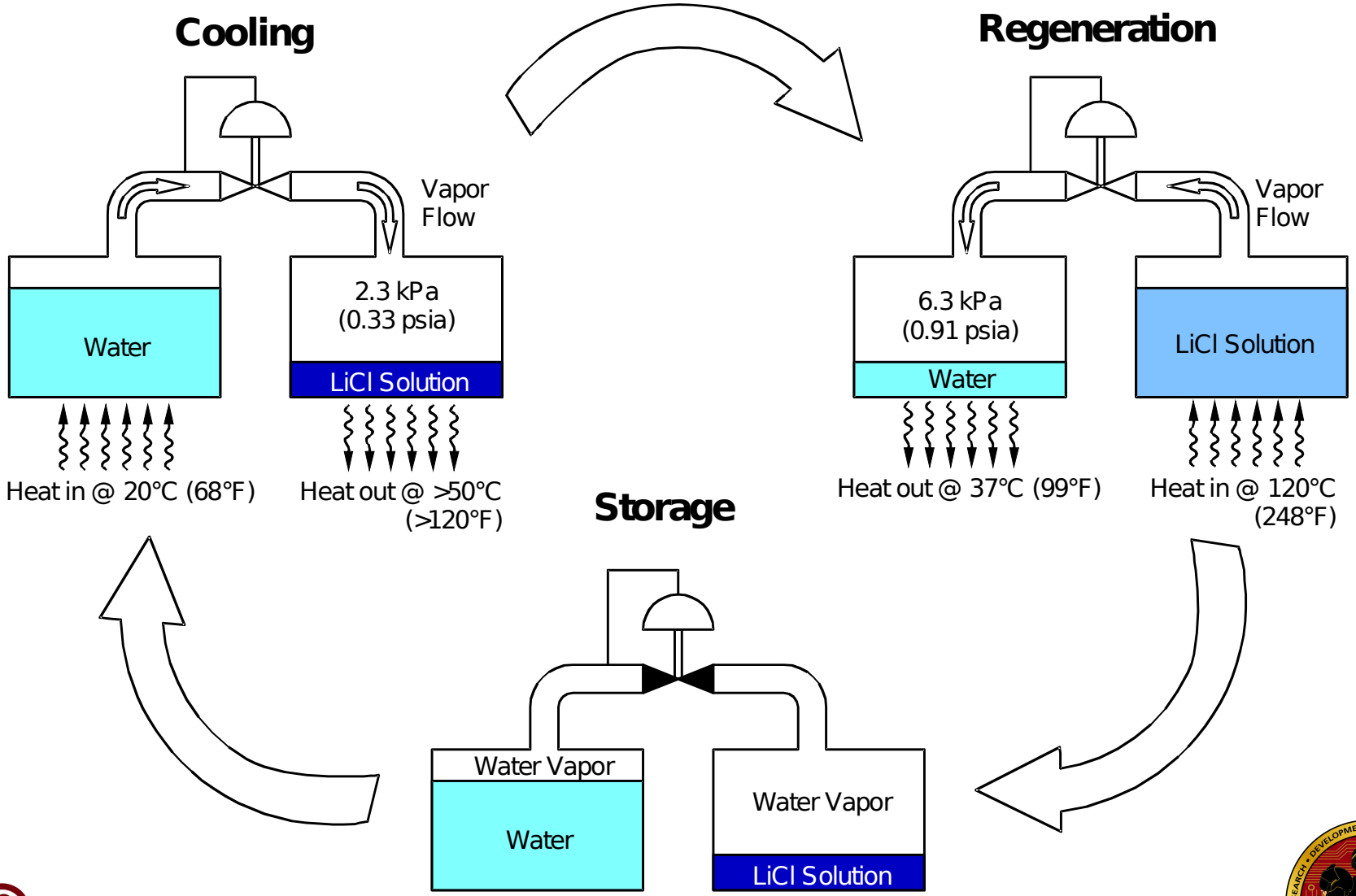
- **Encourage adequate hydration in hot climates**
  - **17 fl oz (0.5 L)/hr for temperature < 100°F**
  - **34 fl oz (1 L)/hr for temperature > 100°F**
- **Very challenging weight/heat transfer requiremen**
  - **32 fl oz water (0.95 L) starting at 110°F**
  - **Cooling spec: 20°F in 10 min**
  - **Refrigeration requirement: 74 W (253 Btu/hr) and 12 W-hr (41 Btu)**
  - **Maximum weight of hardware: 4 oz (113 g)**
- **Calls for innovative cooler design**
  - **No electric power**
  - **Extremely lightweight**
  - **Inexpensive**



Data from Army WPSM Program

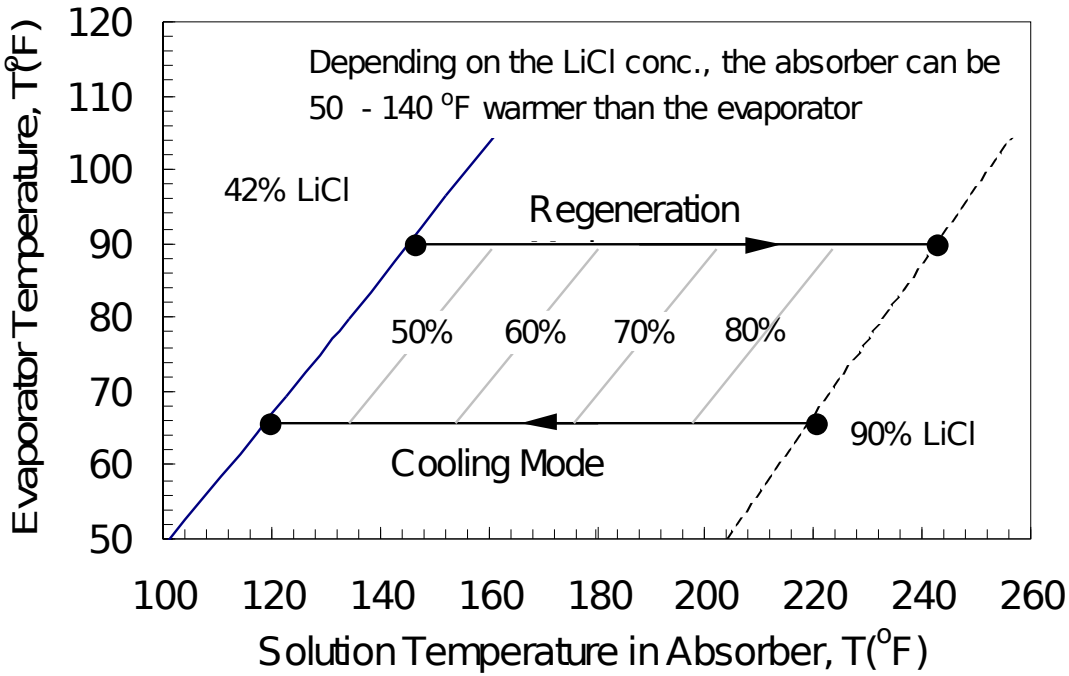
WBGT = Wet Bulb Globe Temperature

Cooling by Absorption



Thermodynamics

- **LiCl solution has strong affinity for water**
- **Vapor pressure over LiCl solution is much less than over pure water**
  - **The higher the LiCl concentration, the lower the vapor pressure**
- **Typical equilibrium conditions:**
  - **90% LiCl @ 215°F with H_2O @ 70°F**
  - **50% LiCl @ 145°F with H_2O @ 70°F**
- **Water vapor will flow from lower temperature water to higher temperature LiCl solution**
  - **Cooling by evaporation**



Refrigerant	kJ /kg	W-hr/kg
Latent heat of evaporation for water	2450	695
LiCl/water pair, 90% to 42% LiCl	1200	333
Latent plus sensible heat for liquid nitrogen	433	120
Zeolite/water pair	408	116
Latent heat of fusion for water ice	333	92
Latent heat of R134A	227	63

Proof of Feasibility

- **Can the ICE provide enough cooling?**
  - **Subscale laboratory tests of key components:**
    - » **Heat sink**
    - » **Integrated system**
    - » **Fabrication from lightweight, inexpensive materials**
- **Can the system be easily regenerated?**
  - **Demonstrated by laboratory tests**
- **Will the system be lightweight?**
  - **Demonstrated use of lightweight, inexpensive materials**
  - **Phase I test data show size of components**
  - **Estimated weight based on the lightweight materials**

Evaporator/Absorber Performance

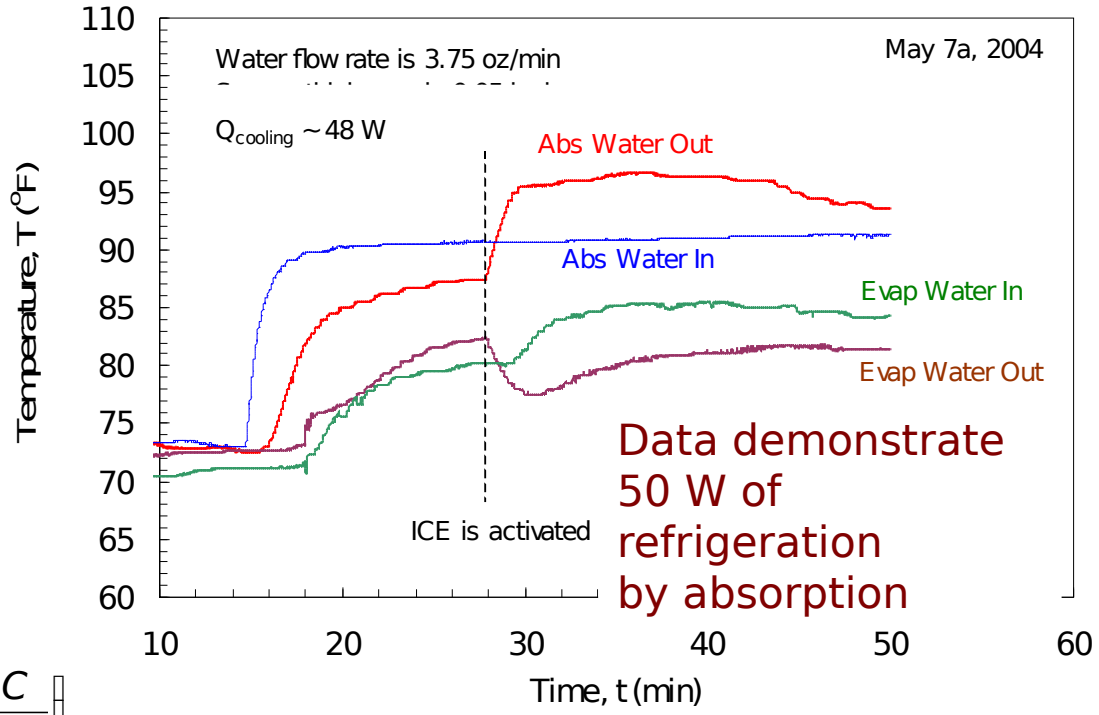
- **ICE activated @t ≈ 13 min**
- **Absorber ΔT ≈ 110°F - 90°F = 20°F = 11°C**
- **Heat transfer to absorber:**

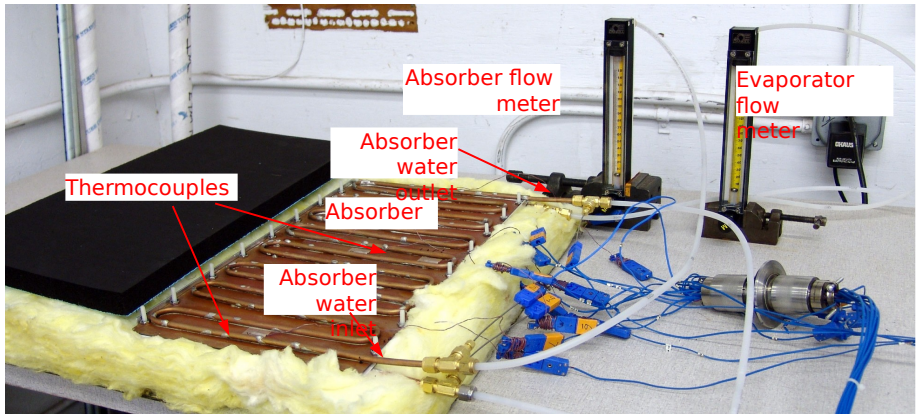
$$q = \dot{m} c_p \Delta T$$

$$= \left[\frac{75\,g}{\min}\frac{1\min}{60\,s}\right] 4.2 \left[\frac{J}{g \cdot {}^\circ c}\right] 20{}^\circ F \left[\frac{1{}^\circ C}{1.8{}^\circ F}\right]$$

$$= 58 W$$

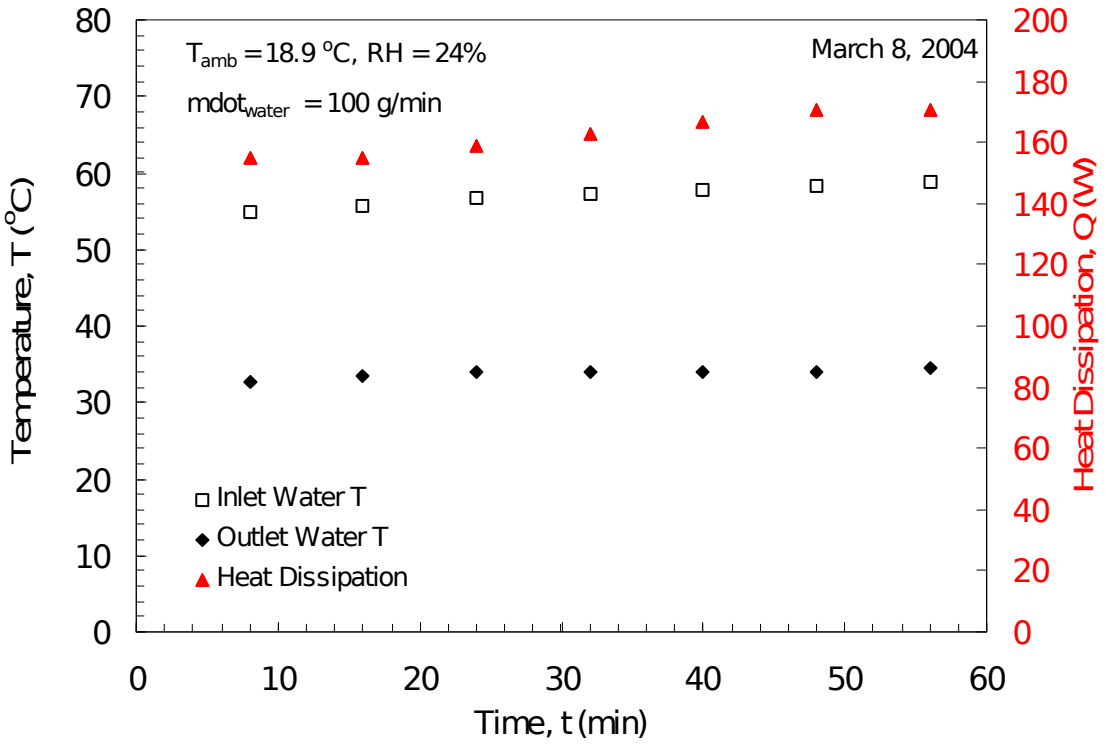
- **Heat transfer from evaporator = 50 W**





Heat Sink Testing

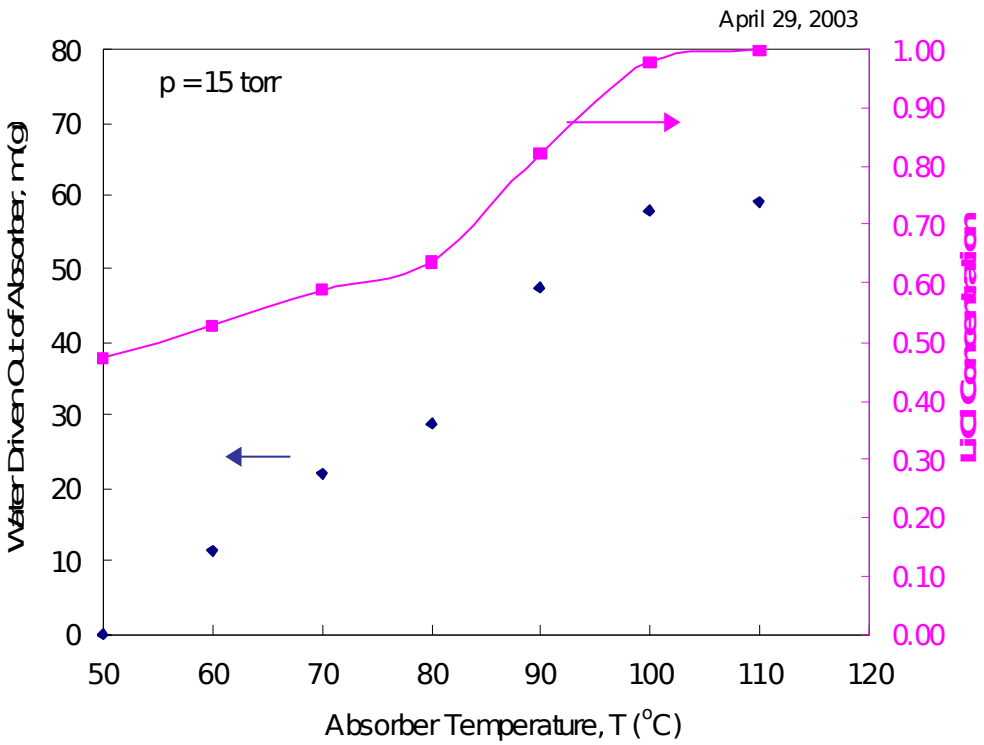
- **Heat sink needed for heat rejection from refrigeration process**
- **Water flows through the heat sink**
- **Feasibility testing**
  - **Heat sink tested vertically**
  - **One-sided test**
  - **Heat sink provided 160 W (543 Btu/hr) of cooling at 90°F (32°C)**



Drop in Water Temperature
Implies 160 W (543 Btu/hr) of Cooling

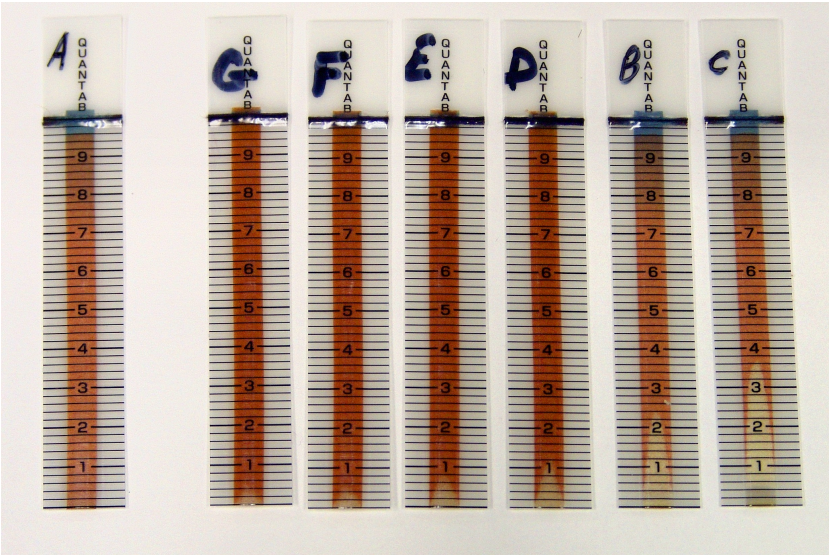
Regeneration Demonstrations

- **Demonstrated regeneration using absorber tubes**
  - **Began with a tube charged with dilute (~ 50%) LiCl/water solution**
  - **Heated to series of increasing temperatures at p = 15 Torr**
  - **Repeated six times**
  - **No degradation in refrigeration performance**
- **Regeneration performance matches thermodynamic models**
  - **Extrapolations of LiCl/water equilibrium data**
  - **Predicts complete regeneration at T 120°C (250°F)**



LiCl Leak Detection

- **QuanTAB chloride titrators manufactured by Hach**
- **Tested sensitivity in LiCl/water solutions with specified concentrations**
- **Sensitive down to 1 ppm molar concentration**
  - **(Test H @ 1ppm not shown in photo)**
- **Titrators in drinking tube would change color to indicate presence of LiCl**

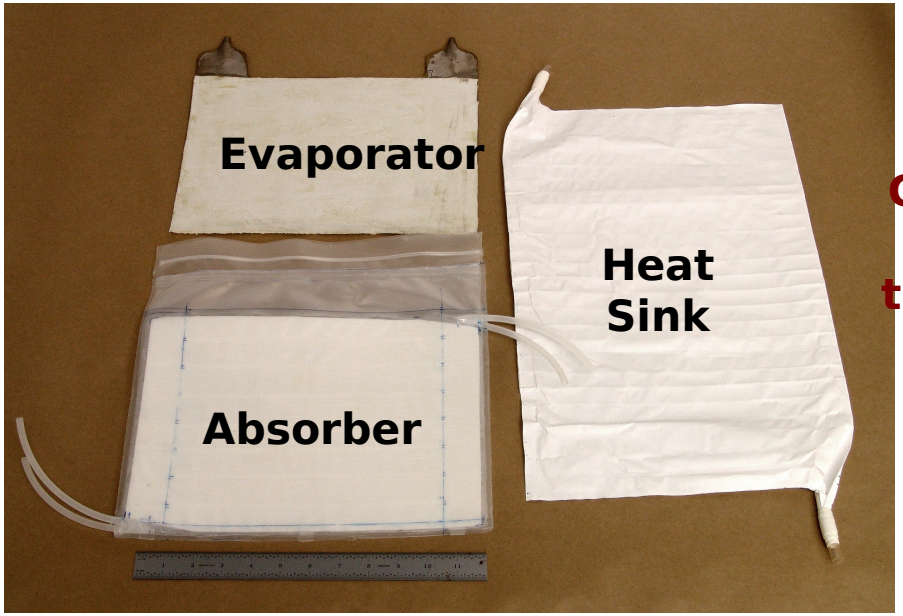


Safety Features

No LiCl in drinking water	The LiCl/water solution will be separated from the drinking water by rugged membranes.
No contact with LiCl solution	All LiCl solution will be contained in a rugged membrane. No solution leaks through the membrane during normal usage
Leak detection	In the unlikely event that LiCl solution leaks into the drinking water, the leak can be detected at very low concentrations (1 ppm) using inexpensive test strip technology.

Creare

Phase II Objectives



Components Demonstrate Feasibility of Fabricating the ICE Using Inexpensive, Commercial Polymer Materials

- High cooling power and capacity
- Light weight and compact (160 g, 10 in. long x 1 in. diameter)
- Safe (LiCl contained, leaks detected at very low concentration)
- Reusable
- Rugged and easy to use
- Low cost
- Scalable (2L bladders in future hydration system)

Conclusions

- **Proof-of-concept tests have shown the feasibility of the absorption ICE concept**
  - **Key processes demonstrated**
  - **Critical materials identified and tested**
  - **Analysis/design models have been verified**
  - **Scale-up of these data show that the Phase II ICE can meet thermal specs at 160 g**
- **Phase II will produce optimized, field-tested prototypes**